

THE THERMO-INHIBITORY APPARATUS.

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IT was first observed by Sir Benjamin Brodie in 1837, after an accidental injury to the spinal cord of a patient, that the temperature between the scrotum and the leg was 111° F. The breathing in this case was carried on by the diaphragm, and he lived twenty-two hours after the injury. Towards death his respirations were 5 to 6 per minute. Prof. Dunglison has seen in many hemiplegics an increased temperature on the paralyzed side. It has been noted by a large number of observers that if an animal has its spinal cord divided, the temperature of the ambient air being high, that the rectal temperature rose. If the air temperature was low, the animal's temperature fell. It has been shown by Naunyn and Quincke that the rise is mainly due to an action going on in the animal and not to the temperature of the air being higher than usual. In this paper we propose to give the results of partial division of the spinal cord, or rather, section of its different columns, and its effect upon the rectal temperature, heat production, and heat dissipation. One of us, Dr. Ott, has already shown that section of the lateral columns of the cord was followed usually by increased exhalation of carbonic acid. This increase of carbonic acid was not due to circulatory disturbance, for the blood pressure after partial division of cord falls, which would not favor increased changes in the tissues and consequent increase of carbonic anhydride. The blood runs rapidly through the widened channels, for the vaso-motor nerves in the lateral columns have been either injured or divided, and it is not probable that tissue-change is increased. Neither does the activity of the respiratory apparatus cause the increase

of carbonic acid, as the section diminishes the number and amplitude of the chest movements. These data show that the increased amount of carbonic acid expired is due to the removal of some influence which restrains the chemical movements of the tissues.

Method.—Etherized cats and rabbits were used, and the number of experiments was twenty-five. The animals were operated upon in a room eight feet wide and thirty-two feet long, with a free circulation of air. A thermometer placed immediately above the operating table noted the temperature in which the animal was during the period of observation. To determine how much the temperature of an animal rose, we opened the spinal canal of an animal, leaving the dura mater intact, and observed that the temperature of the rectum rose a degree in an air temperature of 102 for an hour. It is difficult to accurately estimate the increase, as the animal's struggles will also increase it. In all the animals the cord was divided at about the eighth dorsal vertebra. When the spinal gray was divided, the rise of temperature was .8° F. in Exp. 6, and a fall of 2.8° F. in Exp. 3.

When the anterior columns were nearly divided, there was a rise of .9° F., Exp. 12, whilst when the posterior columns were divided there was a fall of .3° F., Exp. 11. When the lateral columns above or in conjunction with the gray or part of the posterior columns were divided, then the rises of temperature were .7° F. in Exp. 1, 1.2° F. in Exp. 9, 1° F. in Exp. 4, 2.9° F. in Exp. 5, 2° F. in Exp. 2, and 2.4° F. in Exp. 7. All these experiments and others exhibited the greatest rise when the lateral columns were divided. Hence it is fair to infer that in the lateral columns run fibres whose division permit a rise of temperature behind the point of section. The question now arises, To what is this increment of temperature due? Is it generated by increased production or diminished dissipation? To determine this, we used d'Arsonval's calorimeter surrounded by felt, feathers, and saw dust. The air was aspirated through a narrow leaden tube coiled around the chamber containing the animal, and immersed

in the water chamber. By means of a trap door in the roof the temperature of the room was kept about a degree above that of the calorimeter. The error of this instrument for each degree that the air is above that of the calorimeter is $.025^{\circ}$ F., which cannot affect the accuracy of our results. The tabulated results are as follows:

Exp. 1, Cat, weight, 3.32 lbs.

First hour.		
A. T.	R. T.	C. T.
101.4	102.5	99.5
101.	102.1	99.8
Heat dissipation,		12.51
Heat production,		19.67

Lateral columns divided.

101.4	101.6	99.875
100.7	104.7	100.15
Heat dissipation,		11.47
Heat production,		20.04

It will be noted here that the temperature of the animal normally rose, because there is not a free circulation of air in the calorimeter, although quite sufficient for the purposes of respiration.

Exp. 2, Cat, weight, 4 lbs.

A. T.	C. T.	R. T.
100.	99.	102.2
100.7	99.5	105.5
Heat dissipation,		22.94
Heat production,		32.90

Lateral columns partially divided.

100.5	99.55	102.8
100.7	100.2	106.8
Heat dissipation,		27.11
Heat production,		40.39

Exp. 3, Cat.

A. T.	C. T.	R. T.
99.	98.2	103.8
101.	99.2	105.5
Heat dissipation,		8.34
Heat production,		14.68

Lateral columns partially divided.

101.	98.7	103.2
101.3	99.2	105.6
Heat dissipation,		20.86
Heat production,		31.66

Exp. 4, Cat, weight, 3.44

A. T.	C. T.	R. T.
101.5	98.575	100.2
100.3	99.	105.4
Heat dissipation,		17.73
Heat production,		32.57

Lateral columns partially divided.

101.	99.	103.4
100.8	99.65	107.8.
Heat dissipation,		27.11
Heat production,		39.67

The increase and decrease of heat units are expressed by curves in Fig. 1, the dotted line being that of heat dissipation, the other line being that of heat production. By examining the curves, we see that both heat dissipation and heat production are increased, the latter more than the former. The temperature curve is given below.

The question follows, How is this increased temperature due to increased production produced? I have already shown that the increase of carbonic anhydride cannot be due to vaso-motor changes or those of a respiratory nature, and for the same reasons are not the origin of the increased production of heat. Prof. R. Meade Smith,¹ in a series of researches, reached the conclusion that with a larger supply of blood the cool skin, even though exposed to excessive and rapid loss of heat, will become warmer, while, on the other hand, the warmer muscle will become cooler. Consequently, he states the conception must be erroneous which is generally held as to the temperature changes in muscle from alterations in the blood supply after section of the nerves. We believe that there is every reason to assume heat centres to exist in the spinal cord which are connected with the production of heat, and sec-

¹ Archives of Medicine, 1884.

tion of the lateral columns means a division of fibres con-

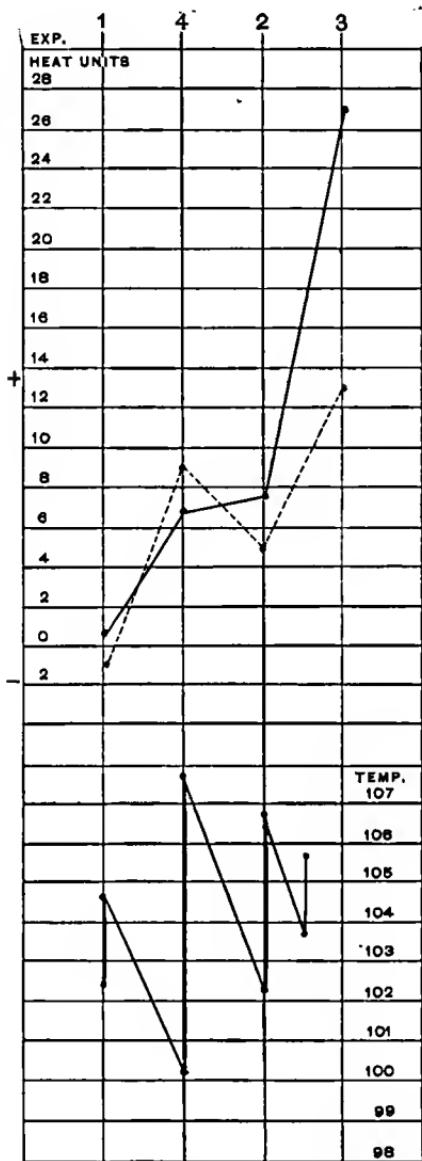


FIG. 1.

ected with centres in the brain which restrain the chemical changes in the protoplasm of the tissues.

Decussation of the Thermo-inhibitory Fibres.

It has already been noted by Schiff¹ after a hemisection of the oblong medulla at the level of the calamus scriptorius that a rise of temperature ensues in the neck, shoulders, seventh and last ribs, and the loins of the side opposite the section. On the side of section, there is a rise in the ears, lower eyelids, nose, and the anterior and posterior extremities. We have tried the experiment of injuring the heat centre on one side of the cerebrum, and noting the temperature on both sides. We found it, however, to be the same. We did note, however, when we divided the sphincter inhibitory fibres, thus causing a rhythm of the sphincters, that a rise of temperature always ensued. Now one of us, Dr. Ott, has shown that they run in the inner half of the middle third of the lateral columns, and they decussate. For that reason we believe that the thermo-inhibitory fibres also decussate, and it is possible that different inhibitory centres in the brain, either thermo- or sphincter-inhibitory, send impulses down the same fibres in the oblong medulla and spinal cord. For Dr. Ott has shown that the sphincter-inhibitory centres lie in the head of the crura cerebri and the parts of the optic thalamus adjacent to them, whilst the heat inhibiting centres lie considerably more anterior to these. We believe the thermo-inhibitory apparatus may be outlined as in Fig. 2. The fibres are connected with centre about the corpus striatum (1), also a point (2) between the corpus striatum and optic thalamus, which Schiff has pointed out as causing upon injury a peculiar cry, and the anterior end of the thalamus (3), whilst they decussate about the nib of the calamus in the oblong medulla (4), and pass down the lateral columns (5). The cortex of the cerebrum is (6).

We believe the body is maintained at a constant temperature by means of the sensory fibres, which call into activity the thermo-inhibitory centres which send influ-

¹ "Untersuchungen zur Physiologie des Nervensystem," 1885.

ences down the lateral columns of the spinal cord, depressing the thermo-genetic centres, which are also in communication with the sensory system, but are so regulated that excessive heat, whilst it may act on the spinal heat generating centres, also acts with much greater force on the cerebral heat inhibitory centres, and thus checks heat production, whilst the absence of heat (cold) allows the sensory stimulation of the inhibitory centres to be less, and thus permits increased production. In other words, the action of the different temperatures on the sen-

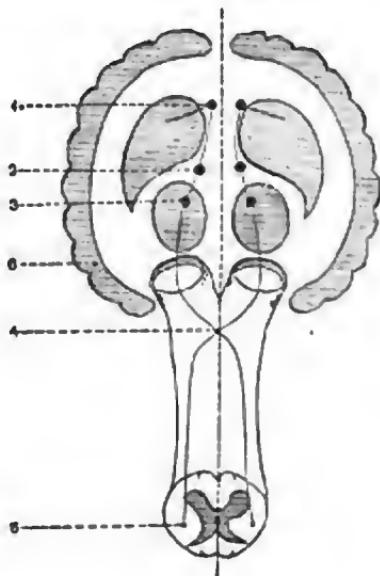


FIG. 2.

sory nerves, calling into more or less activity the thermo-inhibitory and spinal thermo-genetic centres, regulate the temperature of the body.

Compression of Carotids.

It is well known that when the carotids are compressed so as to interrupt the circulation in the brain, then the medullary vaso-motor centre is stimulated, causing a rise of arterial tension. We desired to see what effect it had on the thermo-inhibitory centres. It certainly did not call

them into activity, for there was a slight rise of temperature.

Irritation of a Sensory Nerve.

When a sensory nerve, say the central end of the sciatic, is irritated, the temperature rises temporarily and then falls. In an experiment made with the calorimeter, the sciatic during the second hour was irritated by means of shielded electrodes four times during the hour for a minute. The calorimeter is so arranged that electrodes can be inserted through the aspirating tubes, or even artificial respiration can be carried on in curarized animals without interfering with the accuracy of the experiment.

The results of our experiments were as follows ;

Heat dissipation during the first hour, 38.59.

Heat dissipation during the second hour, 29.20.

Heat production during the first hour, 37.69.

Heat production during the second hour, 28.37.

This experiment proves that heat production and heat dissipation fall as the temperature does from irritation of the central end of the sciatic.

Appended are some of the experiments. R. T. means rectal temperature ; A. T., air temperature ; and C. T., calorimeter temperature.

Exp. 1, Cat.

Time.	R. T.	A. T.
1.45 P.M.	101.6	104.5
1.55	One lateral column divided, part of the other lateral column and the posterior columns.	
2.08	101.5	100
2.13	101.8	Slight sphincter rhythm.
2.45	101.4	
3.35	99.3	98
4.20	100.6	100
4.45	101.6	101
5.10	102.1	101
5.35	102.3	99

Exp. 2.

Time.	R. T.	A. T.
3.10 P.M.	101.3	
3.25	Gray matter and part of lateral column adjacent to it divided ; also posterior columns, sphincter rhythm marked.	98
3.55	101.7	
4.15	102.2	100

4.35	102.4	
5.05	103.1	101
5.30	103.0	100

Exp. 3.

Time.	R. T.	A. T.
1.30 P.M.	102.6	102
1.50	Gray matter divided.	
2.02	102.2	102
2.35	101.8	101
3.00	101.6	101
3.30	101.4	99
3.55	102.	95
4.30	100.8	92

Exp. 4.

Time.	R. T.	A. T.
2.00 P.M.	101.	102
2.08	Gray matter divided and part of right lateral column.	
2.15	101	101
2.40	101.6	101
3.00	101.7	101
3.50	102.4	96
4.35	102	92

Exp. 5.

Time.	R. T.	A. T.
12.35 P.M.	99.9	101
One lateral column cut, the other partially; sphincter rhythm good.		
12.50	100.1	100
1.35	102	101
1.50	102.3	102
2.20	102.9	102
2.40	102.6	99
3.00	102.8	99

Exp. 6.

Time.	R. T.	A. T.
1.00 P.M.	100.3	100
Gray matter divided; no rhythm.		
1.15	101.7	
1.40	102.1	102
2.10	102.3	101
2.30	101.5	99

Exp. 7.

Time.	R. T.	A. T.
1.30 P.M.	103	98
1.50	Posterior columns and part of one lateral column.	
2.35	103.4	100
3.10	104.8	104
3.35	105.2	100
4.22	105.4	100

Exp. 8.

Time.	R. T.	A. T.
2.00 P.M.	101.6	103
2.10	Whole cord divided, except a few fibres of lateral column.	

2.30	102	104
3.13	100.2	104
3.40	101.2	100
4.25	101.3	100

Exp. 9.

Time.	R. T.	A. T.
2.00 P.M.	102	100
2.25	Lateral columns divided.	
2.45	103.2	98

Exp. 10.

Time.	R. T.	A. T.
2.15 P.M.	100.2	100
Section of posterior columns, and injury of gray matter and a lateral column.		
2.55	101.5	100
3.25	101.9	100
3.55	102.4	99

Exp. 11, Cat.

Time.	R. T.	A. T.
3.15 P.M.	102.3	98
Post columns divided.		
4.30	102.2	96
5.10	101.5	102
5.25	101.8	101
5.40	102	100

Exp. 12, Cat.

Time.	R. T.	A. T.
2.35 P.M.	100.4	100
3.00 Anterior columns of spinal cord divided.		
3.20	100.8	100
3.50	101.2	99
4.45	101.3	97

Exp. 13, Rabbit.

Time.		
1.46 P.M.	Right side of body subcutaneously,	103
	Left side of body subcutaneously.	103 $\frac{1}{2}$
2.22	Puncture into thalamus.	
3.14	Left side subcutaneously.	104 $\frac{1}{2}$
3.15	Right side subcutaneously.	104 $\frac{1}{2}$
4.10	Left.	104 $\frac{1}{2}$
4.11	Right.	104 $\frac{1}{2}$

Exp. 14, Rabbit.

Time.	R. T.
2.15 P. M.	102.5
2.45	Both carotids exposed.
3.25	
3.25	
3.30	Clip on both carotids.
3.40	
3.55	
4.15	
4.35	
4.40	Both clips removed.
5.10	
5.40	

Exp. 15, Rabbit.

Time.		R. T.
2.15 P.M.		102.7
2.30	Both carotids exposed.	100.8
2.45		101
3.10		101
3.40	Clips on both carotids.	101.3
3.55		101.3
4.05		101.2
4.20		101.3
4.35		101.2
4.50		101.8
5.10		101.3
5.15	Both clips removed.	101.6
5.30		101.8
5.45		101.3
6.00		101.8

Exp. 16, Cat, weight, 3.68 lbs.

Time.	C. T.	R. T.
2.45 P.M.	63.975	102.6
3.45	64.9	102.3

Second hour.

Time.	C. T.	R. T.
4.00 P.M.	65.	102.9
5.00	65.7	102.3

Irritation of central end of sciatic by Du Bois coil.